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ABSTRACT

Using data collected in a beginning teacher evaluation study, this paper attempts to show that time is an important input in producing learning. First the paper discusses equalization of tax bases in school districts, inequality in the distribution of inputs, and the importance of multiple outputs in schools. Next it describes an economic model of production and choice that can be used to understand and explain the large variation in the amounts of resources--mostly time--that students receive. The paper concludes that a critique of the traditional economic models used in education research can be made into a constructive economic theory of schooling. (Author/LD)

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RESEARCH ISSUES CONCERNING THE PRODUCTION AND FINANCE OF SCHOOLING

Byron W. Brown and Daniel H. Saks

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Research Issues Concerning the Production and Finance of Schooling[1]

Byron W. Brown and Daniel H. Saks[2]

It seems to us that what is most needed in the field of finance and production of schooling is not so much another review of the past literature,[3] but a guide for suggested future literature. We present here eight propositions which we believe to be true and important. We believe they have implications for the kind of research to be done in the area.

The eight propositions are:

1. Aid programs for equalizing tax bases will not even equalize school budgets.
2. Inequality within schools is at least as important as inequality among schools.
3. Recognition of the importance of multiple outputs of schooling is not an argument against quantification of those outputs.
4. Using randomized control groups is not the best way to evaluate school programs -- a model of production and choice is required.
5. The appropriate production model for schools (even where only one subject is being taught) is not the standard one used.

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[2]Byron W. Brown and Daniel H. Saks are on the faculty of the Economics Department at Michigan State University and are also IRT researchers. Saks was on leave to the President's Council of Economic Advisors, where he was Senior Staff Economist for Labor and Human Resources, during the 1979-1980 academic year. This paper was completed prior to his joining the Council and the views expressed herein should not be construed as an official position of the Council.

[3]For two good recent reviews by economists, see Lau (Note 1) and Hanushek (Note 2). For an excellent review of literature taking a classroom perspective, see Barr and Dreeben (1978).

Abstract

Even if aid programs to school districts succeeded in equalizing tax bases, we would still observe large inequalities in expenditures across districts and in resources received by students within classrooms. We suggest that an economic model of production and choice can be used to understand and explain the large variation in the amounts of resources -- mostly time -- students receive. Any attempt to equalize the outcomes of the schooling process at the level of the individual student should consider the allocation of time both to students and subjects. We present evidence to show that time is an important input into the production of learning using data from the Beginning Teacher Evaluation Study.

6. Teachers' and administrators' preferences may be at least as important as technology in determining outcomes in schools.

7. More disaggregated data are not always better in trying to understand school technology.

8. Time is the scarce resource in schools and the organization of time may be the most important variable to be affected by policy.

We will examine each of these propositions in turn, paying special attention to time allocations because it is the focus of our current research. We will present some preliminary evidence on the question of time allocation based on our reanalysis of the Beginning Teacher Evaluation Study (BTES) data collected by the Far West Labs in San Francisco (Fisher, Filby, Marliave, Cahen, Dishaw, Moore, & Berliner, Note 3).

1. Equalizing Tax Bases Will Not Even Equalize School Budgets

A prominent policy designed to equalize schooling in America has been equalization of school system tax bases through various intergovernmental grant schemes. Such a policy preserves the school-district administrative structure for our school systems and the illusion of decentralized decision-making. It will not by itself equalize per capita school budgets any more than universal provision of CARE packages will assure equality of food consumption.

If you want to give people choice about schooling yet you want to make that choice independent of their income and wealth, then you have to devise a scheme to do just that. Of course, you may not want to do that because you may worry that taking an important commodity like schooling out of the reward system will sap parents' desires to work, save, and be creative. Surely that is an empirical question which could be investigated. It certainly has not been so far and it may be one of the main issues in the equalization of school finance. Even if the disincentive costs of equality

were high, though, there may be other policies available to offset those effects. You may decide that every child should have the same schooling no matter who his or her parents are. The meaning of such an equity notion is obscure.

At the heart of school-district finance equalization is an issue which has been a theme of much of our work: the difference between the individual and the group as the proper unit of analysis. The courts seem to have held to the legal fiction that school districts are people and they only buy schooling. If a given tax rate on property is applied to a rich community, it will, in the absence of offsetting aid, generate more funds than if it is applied to a poor community. Therefore, if we could guarantee each community the same tax base we would have solved the problem of inequality. Yet doing this has not equalized school district budgets. The reasons for this go beyond the issue of whether the same rate applied to rich and poor constitutes equal burden in a welfare sense. School districts are political entities composed of families who desire a variety of commodities and services and whose choices are constrained by a limited time and money budget. This means that if you give a community an intergovernmental grant to spend on schooling, its families may choose to spend less of their own money on schooling. They should end up with more money spent on schooling, but not so much as you thought they might.

We have recently (Brown & Saks, Note 4; Note 5) tried to estimate the underlying demands of families for schooling when only the choices of communities of individuals are observed. We have shown that the intra-community distribution of income has an important effect on those decisions and we have estimated the way desired tax rates, after controlling for tax base, still vary with income. Figure 1 shows that relationship.

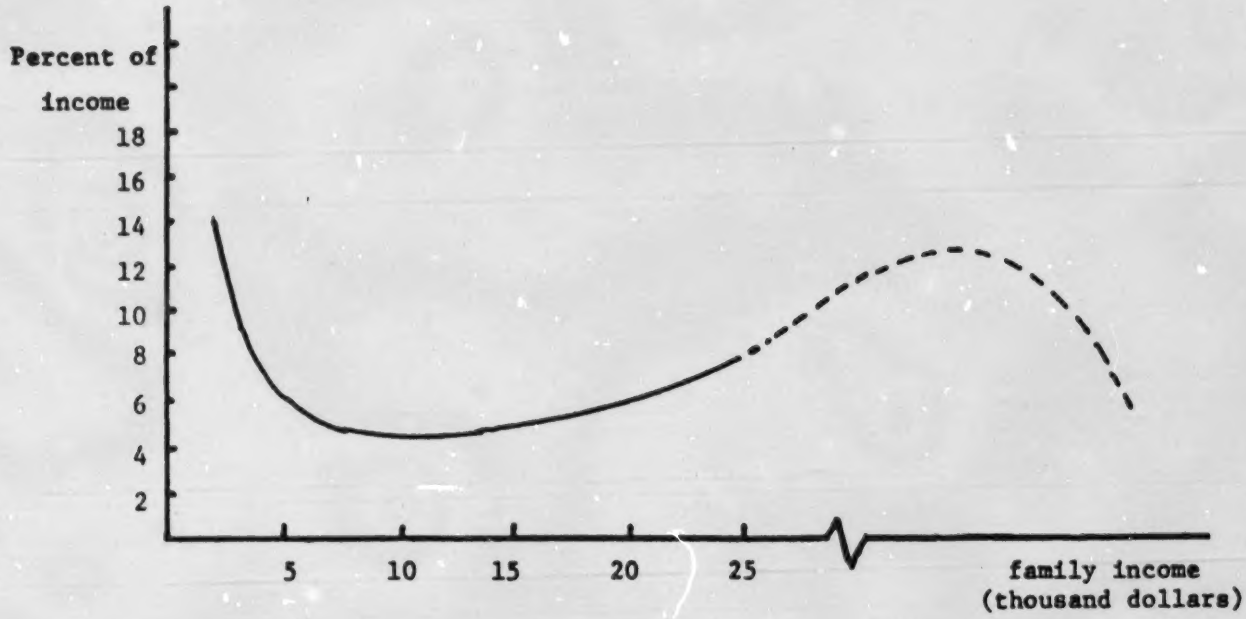

Figure 1. Estimated percent of income families wish to spend on education as a function of family income.

If our estimates are correct, breaking the link between income and school district expenditures is much more complicated than had previously been thought.

2. Inequality Within Schools Is at Least as Important as Inequality Among Schools

Even if per pupil school budgets were equalized across all districts, would that have much effect on inequality in schooling? Just how important is intra-district inequality? This turns out to be a very complicated question. There are both theoretical and practical difficulties in measuring the distribution of inputs. One hint about the distribution of inputs can be found by inspecting the distribution of one of the important school outputs -- scores on achievement tests. Using data for fourth-graders in 1971 from the Michigan Assessment Survey program, it is possible to

calculate the ratio of the variance of the means of school district scores to the mean of the variances of scores within school districts. For cities, the ratio is .15; for suburbs, it is .09; and for towns and rural areas it is .07. Thus the variance of mean scores across districts is small compared to the variance among students within districts.

Inequality in the distribution of inputs at the sub-district level is much harder to observe than at the district level. As we emphasized in Brown & Saks (1975), the difficulties are related to the fact that schools "produce" or teach many students simultaneously in fixed and changing groups or classes. This means that schools engage in multiple output production, and this makes analysis of production in schools a complex task (see Proposition 5). Since students are grouped, it is difficult to observe the inputs that are applied to particular students and to then estimate the treatment effects of those inputs. The problem of observing the precise application of inputs to particular students is both a practical and a theoretical problem.

The practical problem is easier to understand. Just because a child is in a classroom with a teacher does not mean that the teacher is spending much time with that particular child. (We are temporarily assuming that time is only spent on children one at a time.) Further, the time that is spent may be spent differently with different children. The same goes for any equipment and books. In order to sort these things out, an observer has to check on the actual assignments of students to inputs and the detailed way in which those inputs are used. It is not enough to simply assume that the inputs available in the classroom are evenly spread over the students as so many classroom studies do, even those using output data on individual students (e.g., Summers & Wolfe, 1977). The required

observational data are extremely expensive to collect and there is always the danger that the intrusion of the observer affects the observation.

There is one impressive recent source of data (see Fisher et al., Note 3) which tries to do just what is required. The Far West Labs in San Francisco sent highly trained observers into 46 second- and fifth-grade classrooms weekly for most of a year. During their period of observation, they regularly scanned six target students per class and recorded how their time was being spent. This was clearly a massive job, but it appears to us that it was done about as precisely and cleverly as it is possible to do such a thing.

Table 1 reports some relevant statistics from the study about the distribution of time across and within classrooms by subject and grade. Two kinds of time are reported: "total time" which is the minutes in the child's school day devoted to the particular subject and "tutorial time" which is the time during which the child was "engaged" with the subject and the focus of an instructor move, where the "instructor" could be a teacher, teacher's aid, or even a teaching machine.

Consider second-grade reading. Of the 85.3 minutes per day that the average child spent doing reading, only 9 minutes were spent receiving individual attention from some input. Of the considerable variation in total reading time, most of it was accounted for by differences across classes. But only 52% of the variation in tutorial time was variance across classes. There was an enormous variation in time applied to students within classes. If this is representative, then those who view classrooms as places where children receive the same inputs are sadly mistaken. Notice also that these are average times across six weeks in only the fall term so we are not observing a random time allocation for only one day.

Table 1

Time Variation Across Classrooms and Students
(BTES Data for Fall Term)

	2nd Grade: Reading		5th Grade	
	Total Time	Tutorial Time	Reading Total Time	Math Total Time
Minutes/day averaged over all students in grade (standard deviation)	85.3 (20.8)	9.12 (5.62)	112.3 (23.1)	40.5 (13.2)
Standard deviation across classes of average minutes per class	19.6	4.04	21.1	10.6
Ratio of variance of means of time per class to variance of time over whole grade	.89	.52	.84	.64

There is also a theoretical problem in measuring inputs. The problem has to do with what we (Brown & Saks, 1975) call the input exhaustion characteristics of the production process. We normally think of inputs that get applied to the production of outputs in such a way that one more unit of input used on one output leaves one less unit for application to some other output. But that is not necessarily the case where there is joint production of the sort that goes on in classrooms. Some inputs are shared in various degrees (e.g., an explanation to one student that is overheard by others) and these external effects can be both complex and often impossible for an outside observer to see.

We are fond of the analogy between a classroom of many students and an oil refinery which produces a whole range of final products from tar to high octane fuels. It is not possible to assign particular barrels of crude oil (input) to particular barrels of output, though a chemist can define and describe the process and its outputs.

What all of this means is that more data (such as that from the

BTES) on the processes that occur in classrooms is needed so variation in input applications can be measured and a better handle on the input exhaustion problem can be obtained.

3. Recognition of the Importance of Multiple Outputs Is Not an Argument Against Quantification

It is no longer controversial to point out that schools produce a variety of different outputs. Bowles and Gintis (1976) have emphasized socialization outputs, many teachers have emphasized affective outputs, and we (Brown & Saks, Note 6) have tried to show that even where only one output is produced for any child, the fact that students are taught together still requires a multiple output analysis. What worries us, however, is an often unarticulated corollary of this position which seems to be embraced most particularly by those who are upset with some of the simple applications of tests for accountability.

Briefly, the position is that these other outputs are unmeasurable and therefore attempts at quantification are forced to ignore them. We think it is certainly correct to say that these outputs are usually unmeasured, but that does not mean they could not be measured.

Most of the measurement effort in education seems to have gone into the problem of measuring a student's degree of mastery of a subject (where sometimes, as in IQ tests, the content is broadly congruent with the tester's own culture). We believe that those who suggest other outputs have an obligation to be specific and that effort should be devoted to measuring those outputs. In fact, many disciplines have made a good deal of progress in measuring variables not unlike those produced by education. It may only be possible to develop measures which rank people by some criterion, but that is at least as much as an IQ test does. And often the only information needed is the probability

that a student has jumped from one category to another.

Some reading specialists, for example, have argued that one of the objectives of a good reading program is that children learn to like reading (see Brown & Saks, Note 7). We suggested to some of our colleagues in the Institute for Research on Teaching that we ought to try to develop a measure of students' preferences about reading versus other activities and how these shift. In consultation with Joe Byers, Gerry Duffy and his co-workers asked six children in each of 10 classrooms to make binary choices with respect to combinations of six school activities (one of which was reading). The data have not yet been analyzed, but in principle it will be possible to develop a ranking of alternatives or groups of alternatives. It is important to explore the responsiveness and reliability of indices that might be developed from these and other procedures. They need not be expensive to collect and they might be quite useful.

4. Randomized Control Groups is Not the Best Way to Evaluate School Programs -- A Model of Production and Choice is Required

Of all the institutional applications, it seems that nowhere is Fisher's (1945) model of agricultural experimentation embraced so fervently as in educational evaluation. This is not to say that random assignment to control groups is all that common, but rather that the technique is held up as the only correct paradigm.[4] Of course, Fisher's solution to the problem of potential correlation of unobserved with observed treatments in producing outcomes is brilliantly simple. Yet it is only one possible solution to that problem and whether or not it can be used is a matter of convenience and practicality.

[4]For a good recent review of the experimental issue, see Bryk (1978).

When a new seed is assigned to a plot of land, it generally stays there. When a human being in a relatively free society is assigned to a treatment, he or she tends to receive that treatment only if it is better than other available and known treatments. This is a common argument economists have with statisticians who tend to look at evaluation as a simple estimation of conditional means and who find economists' discussions of production functions and utility functions to be pretentious and unnecessary posturings.

But suppose you want to know, for example, if computer-aided instruction improves students' mathematics scores. Randomly pick a group of students from classes to receive so many minutes per day of computerized instruction. The others will be controls. What can happen? Well, for one thing teachers may try to enhance or compensate for the treatment in their other activities with either the controls or the experimental group. Unless you know what the teachers are trying to accomplish and what means they have to accomplish those ends, you cannot possibly analyze the problem. The evaluation must be embedded in a model of production and choice. If it is, then we know how to approach unbiased estimates. Random assignment in this case would only solve part of the problem: correlation of unobserved and fixed student characteristics with the treatment.

Fortunately, there has been substantial progress made lately by Heckman (1976) in figuring out how to correct our estimates in the presence of selection and various truncation and censoring biases. But such techniques require an underlying model of the process. That is why basic research on school processes is so necessary for practical evaluation of educational programs.

5., 6., and 7. Production, Tastes, and Proper Data Aggregation

If a model is required for the evaluation of school effectiveness, what elements should that model include? Propositions 5, 6, and 7 are closely linked, and they have a direct bearing on this question. They deal with appropriate production models for schools, the role of tastes of both teachers and administrators in educational decisionmaking, and the implications of data disaggregation in attempting to estimate models of schooling. These issues are methodologically joined.

The standard economic production model used in the literature has several weaknesses when it comes to helping understand school behavior. It must be modified to account for some of the essential institutional aspects of schools because even in the simplest case of teaching only one subject, the standard model will give misleading results and errant policy recommendations.

The basic ingredient of the standard model of production is the idea of a production function, a rule which specifies the maximum amount of some good which can be produced from any combination of inputs. Economists usually assume that increases in any input, if others are held constant, will increase output, though at a decreasing rate. That is, inputs are productive. They also assume, as part of the standard case, that the inputs are substitutes for each other, though not perfect substitutes (inputs as well as outputs are assumed to be homogeneous commodities). Every unit of an input or output is identical to every other unit. This assumption is rarely, if ever, met in empirical applications in economics, but in the study of educational production it takes on particular importance.

For expositional purposes, assume that two inputs, x_1 and x_2, are used to produce a single output, y. The production function relating these quantities is shown as a series of isoquants[5] in Figure 2. A production isoquant, say y_1, shows all the quantitites of the two inputs which can be used to produce the output level. If the inputs are productive, isoquants such as y_2 represent higher output levels.

Pretend, for example, that x_2 represents the amount of study time a student puts in on a subject and x_1 the amount of tutoring time he or she receives. The output might represent the learning in that subject. If the student has some fixed amount of time, $\bar{T}$, to devote to learning, which allocation between studying tutoring is best ? Which gives the largest output? The solution is shown in Figure 3, in which the straight line gives all the possible time allocations. The best allocation is (x_1^*, x_2^*) since it enables the student to get to the highest isoquant within the limits of the time constraint.

If we knew the parameters of the production function, we could evaluate whether a particular time allocation was optimal or not, or ask which of a series of alternatives was best. While these may appear to be interesting questions, it is unlikely that anyone studying teaching would find much fascination in the answers. That is because the technology of production suggested by this model is in marked contrast to the real world of learning in which students with varied backgrounds and abilities are often taught in classrooms where several subjects are taught. The tutorial versus seatwork alternative in one subject for one student is not an accurate way of compartmentalizing life in classrooms.

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[5] In economist's jargon, an isoquant, or constant quantity curve, shows all the combinations of inputs which yield the same output. Since inputs are usually assumed to be productive, isoquants representing larger outputs lie in the northeasterly direction.

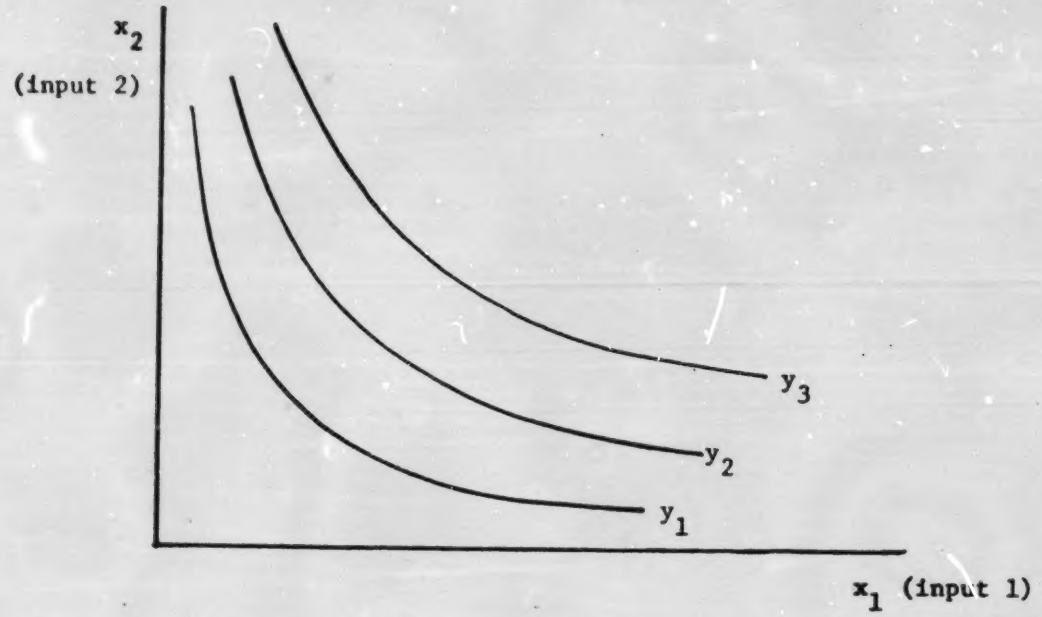

Figure 2. Isoquants for producing a single output from two variable inputs.

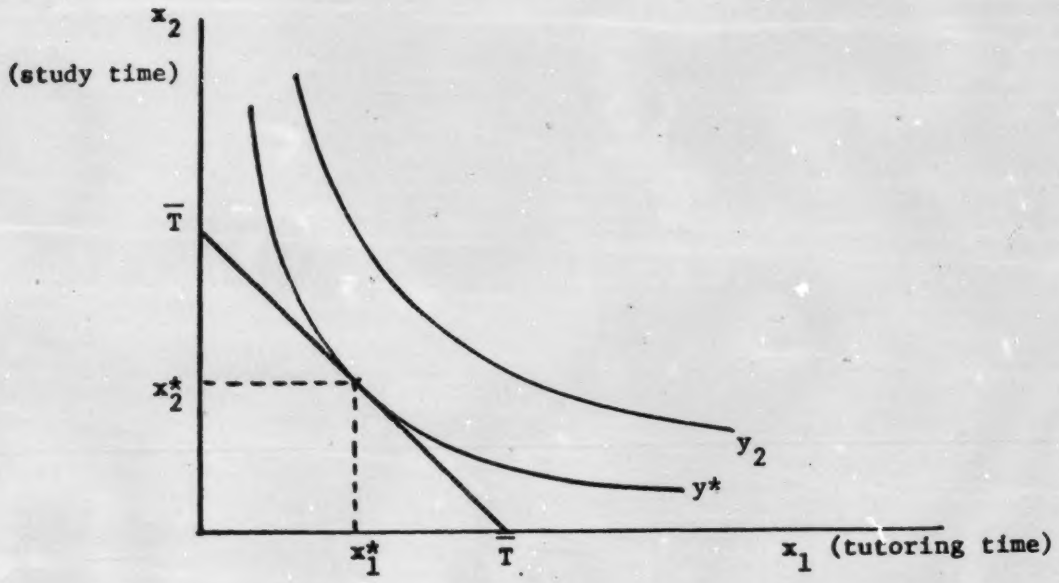

Figure 3. Learning produced from two activities, and the optimal engagement rates in the activities.

Yet the model, in one form or another, has been the mainstay of the educational production function literature. The problems posed by the innerent diversity of subject matters and students are assumed away. Sometimes aggregate achievement scores for classes are used as output measures. And often the input measures used have only the most tenuous relation to the amounts of resources the students actually receive.

Knowledge of input productivities is undeniably important. With it, we can try to buy only the most productive inputs and find combinations of inputs which are efficient. One way to get more results from an increasingly tight school budget is to use those resources that can be bought more efficiently and to buy more of those resources which are more productive. To do that requries a detailed knowledge of the returns from spending in different ways. The standard model has led us astray in two respects, first by misspecifying outputs, and second by misspecifying inputs.

Suppose, instead of the above production model with its single output of one student's learning and several inputs, that we have two students receiving a single input. In order to put part of the input specification problem clearly aside for the moment, we assume the input can be applied to one or the other of the pupils, but not to both at once. Our choices are to give all the input to, say, pupil A and none to pupil B, give all to B and none to A, or give some to each. Every possible input allocation has its ramifications for learning for the two students. One set of possible outcomes for a fixed level of total input is shown in Figure 4 by the line DD'. Its negative slope shows that to get more learning for A means a loss for B.

It is easy to show how using aggregative measures for the inputs and outputs can give misleading results about input productivities (Figure 4). Suppose input is measured by the total amount available to both students and output by the mean learning or scores of the students. The line NN' in Figure 4 shows all score combinations which have Q as their mean. Now increase the amount of the input available so EE' shows the attainable scores. Clearly the input is productive because more learning for each student, or both, is possible when the input is increased. Through an exercise of choice (to be discussed below), a point such as P may be arrived at. Notice that the mean score of the pupils is lower at P than Q since the new line of constant mean, MM', lies below NN'. Higher input yields lower output, at least in terms of aggregate measures (the mean), even though the input is productive.

The phenomenon shown here could be one explanation of why many earlier studies failed to find a relationship between inputs and outputs in schools. While the answer to getting correct results may be to move toward more disaggregated data, there remain important problems of model specification. If we were to disaggregate the students' scores, that is, use student-level output data, we would still get biased estimates of input productivities unless the same thing were possible at the input level. Yet we shall show that proper input disaggregation is not nearly so simple as one might suppose. Indeed, many studies that have succeeded in getting output data on the student level have failed when they came to input data. More often than not, input measures were at the classroom or school level (e.g., teacher characteristics and school facilities). These measure not the input each student receives, but some kind of average that no student may receive.

How were points P and Q chosen in Figure 4? An economist's answer

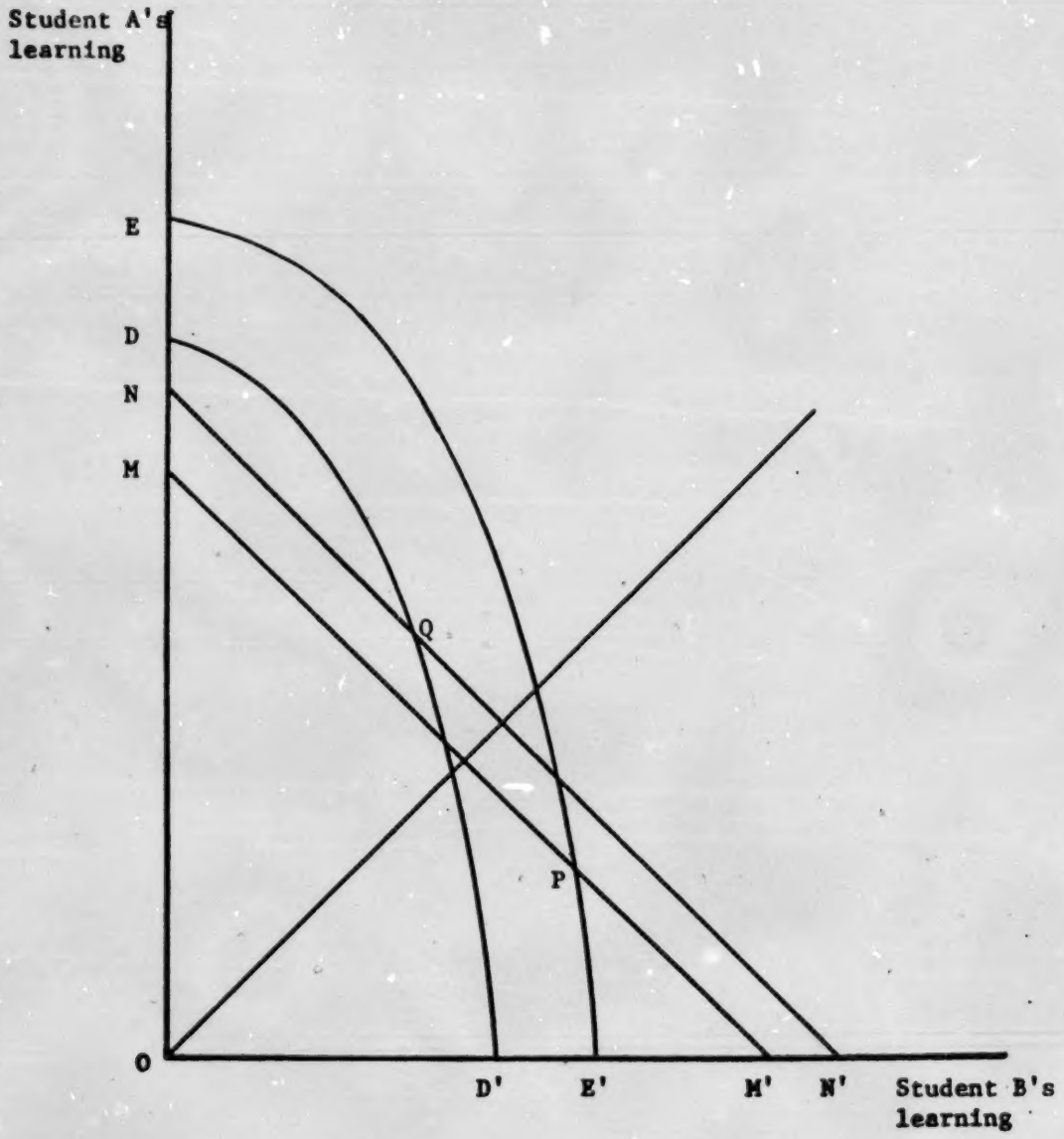

Figure 4. Learning levels possible for two students at two different levels of resource use.

involves the introduction of tastes or values into the model. We cannot, so long as there is more than one relevant output of schooling, ignore non-market values as important determinants of outcomes. This, more than any other factor, is what makes the multiple output case more interesting and analytically more difficult than the single-output case.

Economists solve the problem of subjective value, as opposed to market value, by assuming the existence of a utility function. This is no more than a rule which assigns some unique level of satisfaction or well-being to each combination of goods and services consumed. The utility function is a description of the preferences of an individual.

The tastes embodied in a utility function are conveniently summarized using the device of indifference curves which show all the combinations of goods or services consumed which would yield the same level of satisfaction to a person. Figure 5 shows indifference curves for the consumption of two goods, y_1 and y_2. More of each good is better, meaning that each curve is negatively sloped and indifference curves denoting higher levels of satisfaction lie to the northeast in the figure. That the curves are convex is a way of showing that people value variety in consumption.

Such a structure of tastes can be brought to bear as an explanation of why point P was initially chosen in Figure 4 and how, when input increased, there was a move to point Q. Let the utility level of the teacher or other decisionmaker depend on the scores of the two students: $U = f(S_A, S_B)$. If the teacher maximizes utility, then the scores to be chosen are those which will get her to the highest indifference curve. The optimum will be where an indifference curve is tangent to the relevant output possibility curve, initially point P on line DD' in Figure 4.

The point of introducing tastes into the analysis is two-fold.

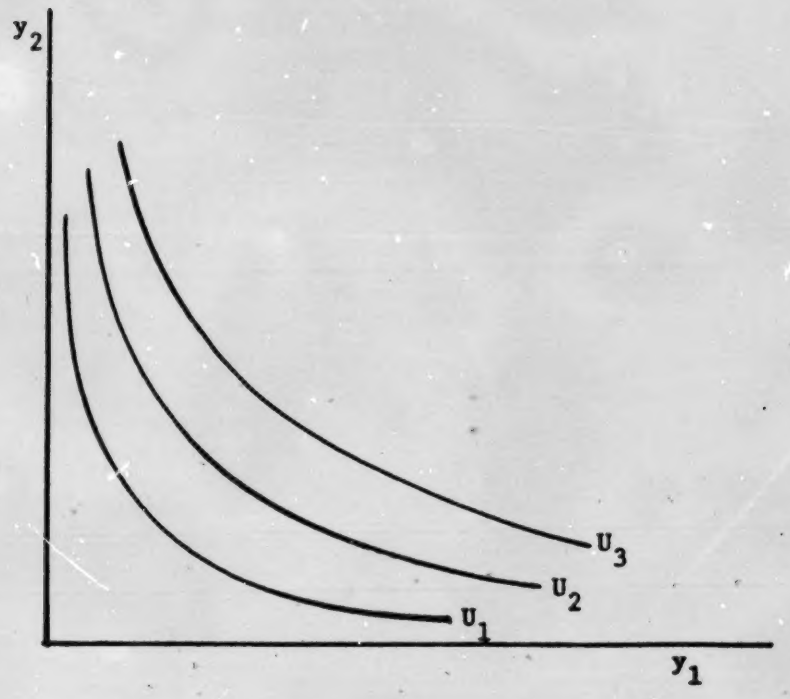

Figure 5. Depiction of tastes or values by a set of indifference curves.

First, it makes clear that when there are multiple outputs in a non-market setting, some values are needed to determine an outcome. If values, the weights different teachers assign to the achievement of different students, vary across teachers, it may be impossible to get good estimates of input productivities at all with the kinds of data available to many researchers. The interaction of technology and tastes may always be present in the generation of data on inputs and outputs so that except in the simplest cases of single-output production, disentangling them to isolate the technology will be impossible.

Second, while values may be necessary to make the model work, it is not clear whose values are being talked about. While we attributed them to the teacher in the paragraph above, that was merely an expositional convenience. School administrators have values which are felt in classroom decisions and so do parents and others outside the school. How the values of these groups interact and affect inequality within classrooms are important but neglected issues. Clearly, which students receive which school resources is a question important to school costs and equity that cannot be forgotten in evaluating school efficiency. (Note that on the utility maximizing criterion, the point Q in Figure 4 is best for the increased expenditure level even though the mean score of the students is lower there than at P where less is spent.)

We now turn to a more realistic model of production in schools, one which incorporates what economists call jointness in production. Jointness, alluded to above, means that increasing the amount of some input devoted to an output will not reduce by the same amount the quantity of that input used for other outputs. A common example in economics is the production of hides and beef from a single input, cattle. Increasing the rate of slaughter increases the input to both hide and beef output. The input is, in a sense, shared by the two processes of production. Note that it does not make sense to try to assign part of the cattle input to each of the outputs. Disaggregation of the input to the respective production processes is impossible. Thus, at least in theory, the solution to finding the input-output structure through increased disaggregation may not be feasible. Individual data cannot solve the problem of estimating input productivity in such a world.

The relevance of this to schooling is that when a group of students

are taught by a teacher at the same time they are lectured to, for example, we have exactly the kind of jointness described above. We cannot say how much of the input, lecturing time, gets assigned to each student in a group. They all get to use all of the lecturing-time input. It would be wrong to say that in a group of ten students lectured for one hour that each got 1/10 hour of the teacher's time. A proper analysis would have to account somehow for the group context in which the time was applied if we were to understand its effects on individuals.

8. Time is the Scarce Resource in Schools and the Organization of Time May Be the Most Important Variable to Be Affected by Policy.

We have already noted that there is considerable variation across and within classrooms in the application of time to students and that one must distinguish between time that can be shared (e.g., lecture time) and time that cannot be shared (e.g., tutorial time). In this section, we present some preliminary work from our Spencer-supported research on time allocation in classrooms. We feel that such detailed micro analysis is the only way to make serious progress on the issues we have raised.

The theory follows from our previous work on production in schools. We think of the teacher who is presented with a class of students of given characteristics and who has to use his or her resources (mainly time) to achieve the "most desirable" possible characteristics for the students at the end of the school year. It is a formidable management problem which can only be solved approximately in the real world.

Economists find it helpful to construct a stylized mathematical model to help their intuition in such matters. Think of a teacher with a utility function containing only the end-of-year test scores for the students.

The teacher maximizes that utility function subject to production functions which differ for each student and whose arguments are the student's starting score, tutorial time applied to the student, and group time which is perfectly shared but need not have the same effect on all students. Further, there are time constraints such that the sum of tutorial time for all the students plus the group time equals the total time in the teacher's day. The optimization rule will then be for the teacher to allocate time so that: (1) the marginal product of tutorial time for each student multiplied by the marginal utility to the teacher of increasing that student's score by one unit must be equal for all students and (2) these must in turn each equal the sum of the products of group time's marginal product for each student and the teacher's marginal utility for a unit score increase for that student. Put another way, time must be allocated so that the value of its marginal product is equalized in all uses. This is a standard economic result for a static optimization model. The static model is helpful because it provides the information that observed variation in time allocations is based on variation in productivities of time spent on different children and differences in their valuation by the teacher. This insight must be the basic building block if these underlying differences are to be identified a more complex, dynamic model elaborated. We do not pursue that quest here.

Does variation in quantity of time spent with particular children and subjects really make any difference after all the stable characteristics of the students and teachers are accounted for? This is probably one of the most stringent tests that can be posed for the effectiveness of small time variations. After all, much of the existing production-function literature seems to emphasize the importance of children's socio-economic characteristics and teachers' competence as the main causes of variations in school

effectiveness.

The BTES data (Fisher et al., Note 3) can be used to answer such a question because each child was tested at three points in time: the beginning of the year (point 0), after the fall term (point 1), and at the end of the year (point 2). Further, researchers observed the "engaged" time each child actually spent in group instruction, tutorial work, and seatwork.

Consider a linear regression model where test score (S_{1n}) for the n^{th} child at, say, point 1 is a linear function of the minutes of each kind of time devoted to that child in the preceding period. In addition, the equation contains the test score at the beginning of that period, a dichotomous variable (f_n) for each (but one) child, and a normally distributed stochastic term. A similar equation can be defined for the score at point 2. These are equations (1) and (2).

$$S_{1n} = \alpha_1 + \sum_{i=1}^{3} \beta_i t_{i1n} + \gamma S_{0n} + f_n + \varepsilon_{1n} \qquad (1)$$

$$S_{2n} = \alpha_2 + \sum_{i=1}^{3} \beta_i t_{i2n} + \gamma S_{1n} + f_n + \varepsilon_{2n} \qquad (2)$$

Assuming that the structure of the equations is the same except for a shift in intercept between the two periods, differencing the two equations will result in equation 3.

$$S_{2n} - S_{1n} = (\alpha_2 - \alpha_1) + \sum_{i=1}^{3} \beta_i (t_{i2n} - t_{i1n}) + \gamma (S_{1n} - S_{0n}) + (f_n - f_n) + (\varepsilon_{2n} - \varepsilon_{1n}) \qquad (3)$$

If the random errors are independent between the two equations, the parameters can be estimated by ordinary least squares while completely controlling for all fixed classroom, home, and student effects. Table 2

Table 2

Ordinary Least Squares Regressions for Scores Changes

Grade, Subject	VARIABLE COEFFICIENTS (STANDARD ERRORS)					$\bar{R}^2$
	Difference in Time in Minutes/Period			Change in Period's Starting Score	Constant	
	Seatwork "Engaged"	Tutorial "Engaged"	Group "Engaged"			
Second Grade Reading	.000627 (.00225)	.0103* (.00623)	.00285 (.00289)	-.299** (.0898)	26.7** (6.02)	.07**
Second Grade Math	.00824* (.00499)	-.00947 (.0136)	.013** (.00656)	-.156 (.119)	25.7** 4.64	.02
Fifth Grade Reading	.000303 (.0012)	.00495 (.00795)	.00109 (.00253)	-.338** (.102)	12.3** (3.20)	.06**
Fifth Grade Math	.00306 (.00317)	-.00482 (.0133)	.00884* .00489	-.415** (.0983)	19.3** (4.00)	.11**

*Significant at the 10% level; **Significant at the 5% level

reports the results of such regressions for two grades and subjects.

There are a few things to notice about these equations. First, with the exception of reading at the fifth-grade level (where those who are going to learn to read by normal instruction have probably done so already) every equation contains at least one significant coefficient for some time variable. Second, the important time variable seems to vary with subject. Group time is especially productive for mathematics (and also seatwork in second grade) while tutorial time seems to make the difference for second-grade reading. Third, the constant is large and positive which indicates that more learning takes place in the second than the first period. This is consistent with a situation where teachers learn how to teach and students learn how to learn with each other over the year. Fourth, the coefficient on change in starting scores is significantly negative. This is almost certainly an example of regression toward the mean due to measurement error in the test. Remember that these equations already contain a variable which controls for fixed abilities of the students.

The preliminary results from estimates of the fixed effects model are quite encouraging. There is, however, one other point we want to make. Time allocations are themselves important variables to be explained. Not only do these vary across students (Table 1), they also vary over time, suggesting that we need a dynamic model. Table 3 gives some indication of the importance of this dynamic property.

We have calculated Theil's Inequality Statistic for two distributions, namely the distribution of total allocated time across students for our two periods of observation. This statistic (I) is the mean sum of square deviations of time between the two periods for each child divided by the mean sum of squares of times for the children in the first period.

The more the time distribution differs across the children between the two periods, the larger the index. (Notice again that these are average daily times for the periods in question.) We can separate this index into three components: (1) I^c, which represents the difference in the two distributions due to a shift in the central tendency of the distributions, (2) I^v, which represents a shift in the variance of the distributions, and (3) I^r, which represents changes in the distributions due to incomplete covariation of the elements of the distribution. Most of the inequality in the two time distributions for each grade-subject is due to children being shifted within the distribution. Thus there is adjustment of time devoted to particular children even though the general distribution of time stays roughly the same. Understanding why this is happening in such a systematic fashion between periods is just one of our important problems in this research.

These preliminary results give us hope that our critique of the traditional economic models used in education research can be made into the building blocks of a constructive economic theory of schooling. If we are right about all of this, it is important to try to pursue these sorts of inquiries in our newly funded research and not just to redo more of the same old studies which really have not taken us very far.

Table 3

Theil Inequality Statistics for Total Time Distribution Between Periods

	2nd Grade Reading	5th Grade Reading	5th Grade Math
$I = \{[\sum_n (t_{n2} - t_{n1})^2]/\sum_n (t_{n1})^2\}^{1/2}$	.203	.193	.344
$I^c = n(\bar{t}_2 - \bar{t}_1)^2/\sum_n (t_{n2} - t_{n1})^2$	.032	.015	.057
$I^v = n(S_2 - S_1)^2/\sum_n (t_{n2} - t_{n1})^2$	.082	.022	.0
$I^r = 2n\ (1-r)\ S_2 S_1/\sum_n (t_{n2} - t_{n1})^2$	.89	.963	.943
r	.56	.48	.41

Definitions: t_{n2} is total time ("engaged" and "not engaged") allocated to subject (in average minutes per day) for the n^{th} child in the 2^{nd} period. S_2 is the standard deviation of time across children in the 2^{nd} period, and r is the zero order correlation coefficient.

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